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ABSTRACT

Geologic Mapping.- ERTS-1, Skylab, and RB-57 imagery acquired within days of each other of the San Rafael swell have enabled geological mapping of individual formations of the southern portion of this broad anticlinal feature in eastern Utah. Mapping at a scale of 1/250,000 on an enhanced and enlarged S-190B image has resulted in a geological map showing correlative mappable features than are indicated on the Geological map of Utah at the same scale.

An enhanced enlargement of a S-190B color image at a scale of 1/19,200 of the Bingham Porphyry Copper deposit has allowed comparison of a geological map of the area with the space imagery map as fair for the intrusion boundaries and total lack of quality for mapping the sediments. Hydrothermal alteration is only slightly evident on space imagery at Bingham but in the Tintic Mining district and the volcanic piles of the Keg and Thomas ranges, Utah, hydrothermal alteration is readily mapped on color enlargements of S-190B (SL-3, T3-3N Tr-2).

Several sites of calderas have been recognized and new ones located on space imagery. Attempts to locate the boundaries of three previously suggested calderas in the Topaz, Desert, Drum, and Keg mountain area, Utah, have been made with limited success on an enlargement of (SL-3, S-190B, 02-3N, Tr-2) a color image. New calderas have been recognized and their boundaries have been readily located by space imagery in the Escalante area, Utah, and in the environs of Timber Mountain, Nevada.

Geomorphology.- As the search for hidden mineral deposits in the Basin-Range province extends into post-ore blankets of Quaternary alluvium or volcanics, there developed a need to select those pediment or valley sites where only a thin veneer of alluvial material existed. Such sites required recognition and study of pediments, alluvial fans, bajadas, and valleys with shallow alluvial fill. Some specific examples and applications are sited.

Instrumentation - Exploration Geology and Geothermal Studies.- One of the "tools" developed through this contract is a mercury soil-gas analyzer that is becoming of significant use as an aid in locating hidden mineralized zones which have been suggested from space imagery. In addition, this "tool" is a prime aid in locating and better delineating geothermal sites.

The collector consists of a hemisphere equipped with a battery powered fan. Filters are used to collect contaminants. Silver screen disks (180 mesh) are placed in the orifice of the fan which is operated for ten minutes. The screen is heated at 650°C in a portable flameless atomic absorption instrument and the released Hg content is measured with a precision of ± 2 ppb.

Known geothermal areas that have been tested have given background readings of between about 10-50 ppb of Hg with anomalous samples collected near and as far as one-half mile from geothermal and drill hole sites that have measured in excess of 1300 ppb of Hg.

Further specific examples of the successful use of this tool are:

- (1) extending the trend of the Comestock lode vein into post-ore alluvial and volcanic areas that resulted in more successful exploration drilling results,
- (2) detecting anomalous values over porphyry copper deposits in contrast to surrounding non-altered nor mineralized areas, and

(3) other specific areas.

A notable test site in the Robinson Mining district was selected after space imagery of both EREP and ERTS-1 imagery indicated an area of potential post-mineralization covered with Tertiary dacite. A major fault through the volcanics allowed rapid erosion of the west portion of the area resulting in small inliers of Permian limestone to be exposed. Large positive aeromagnetic anomalies occur over nearby mineralized areas and known large production mines as do similar anomalies over the volcanic area although it is not known if the volcanics or a speculative buried intrusive, mineralized or not, is the cause of the positive magnetic anomaly. An extensive Hg soil-gas study in selective portions of the volcanic area has resulted in detecting several Hg anomalies of more than 100 ppb with background values of less than 10 ppb that correlate with aeromagnetic anomalies. Highly speculative explorative drilling is planned for the near future on one or two of these anomalies.

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INTRODUCTION

The application of Space Imagery to geological studies in Utah and Nevada was initiated with the ERTS-1 program on July 23, 1972. Prior to this time, no space imagery from space sensors located normal to the surface north of 37° latitude, the southern border of Utah, had been obtained. Some high altitude, fixed-wing air craft imagery along with low-elevation airphotos were available.

In addition to ERTS-1 imagery of Utah and Nevada, EREP imagery was also acquired for the purposes of this remote sensing study that consisted of S-190A, S-190B, S-192 photography and imagery along with RB-57F photography acquired at elevations near 57,000 feet.

Although the prime objective of these studies using space imagery has been mineral exploration, application to other geological specialties could hardly be ignored.

Figure 1 is a photo of a map of Utah and Nevada on which is indicated all of the ERTS-1 imagery received along with the EREP (Skylab) paths. The ERTS-1 imagery nadir positions are indicated by colored pins, with the color indicating the cloud cover of this specific imagery along with tags indicating the date of the recording of the imagery in space.

ERTS false color composite and EREP imagery enlargements display anomalous color changes in rock units which are closely related to some known and potential mineral deposits. This simple and direct use of black and white and color anomalies for selection of mineralization targets has been profitable in many areas (Short and Lowman, 1973). Correlation of such imagery anomalies with larger scale multispectral photography, geologic maps, geophysical surveys, etc. is proving to be productive.

Our principal objective of the application of space imagery was to determine its value in the location of new major ore targets. In this study the ERTS and EREP imagery was used as color composites and black and white photographic enlargements with scales between 1:20,000 to 1:1,000,000. ERTS tapes, analyzed and correlated by digital computer processing is of increasing value for the exploration photogeologists. A prime example of such is some of the studies performed by personnel of the Jet Propulsion Laboratory in collaboration with U. S. Geological Survey personnel on the Goldfield Nevada area (Rowan, L. C., et. al., 1974).

In summary, therefore, the purpose of this paper is to report on the utilization, method of study, and the results of the application of space imagery to geology including mineral exploration in the states of Utah and Nevada.

STUDY OF IMAGERY

The examination and study of imagery was done essentially by visual study using light tables to which is attached a Mikkon binocular microscope of variable magnification up to 50X. Lately, some ERTS positive transparencies are being studied using Add Color viewers that allow more visual latitude than the ozalid false color process that we have used extensively.

Imagery features were correlated and compared to ground truth data consisting of geological and geophysical maps, especially magnetic maps. Quarternary features consisting of landslides, fan deposits, and fracture and joint patterns were readily recognized. In addition, Pleistocene lake shorelines, deltas, bars, etc. of Lakes Bonneville and Lahontan, hydrothermal alteration features of known and potentially unknown mineral deposits were studied.

Geologic Maps were made from the imagery for comparison to known geologic features and some of the maps delineated features such as calderas, faults, and potential mineralized areas that had not been previously recognized.

RESULTS OF GEOLOGICAL MAPPING

Oblique SL-3 Image of Utah.- An oblique color photograph of a large portion of Utah and portions of Arizona, Nevada, and Idaho is shown by Fig. 2. The dark portion is not space but the outline of the Apollo Spacecraft window. The contrasts of the reflectivity of water are remarkably well displayed with the light gray colored fresh water Utah Lake located slightly above and to the left of the center of the image. In contrast, the Great Salt Lake exhibits the two lakes separated by the Southern Pacific railroad earth filled causeway with the more saline lake reflecting lighter color and the less saline lake, where much more fresh water streams enter, reflecting a dark blue color. The differences in the colors of the Great Salt Lake are the result of different bacteria existing in the waters of different degrees of salinity.

Only a very few scattered clouds exist to the north or left portion of the image with all other white areas being snow. The Uintah mountains, the Wasatch Plateau, and the Wasatch mountains are all tipped with snow, as are the Rocky and East Humbolt ranges of Eastern Nevada as shown in the lower right corner of the image. In the west portion of the image, those ranges with snow in the higher elevations are the Schell Creek and Snake ranges, Nevada, with the latter two snow capped portions separated by Sacramento Pass. The snow tipped Deep Creek range in Utah is located farther north and on the edge of the Bonneville Salt Flats.

Lake Mead is visible near the right edge of the image as is Lake Powell in the upper center of the image. The San Rafael swell is well displayed in the upper left portion of the image.

Other vertical images of specific portions of this oblique photograph are dealt with in detail in this report.

San Rafael Swell, Utah.- ERTS-1, Skylab, and RB-57 imagery acquired within days of each other of the San Rafael swell have enabled geological mapping of individual formations of the southern portions of this broad anticlinal feature in eastern Utah. Mapping at a scale of 1/250,000 on an enhanced and enlarged S-190B image (Fig. 3) has resulted in a pre-

liminary geological map (Fig. 4) showing more detailed mappable features than are indicated on the Geological map of Utah at the same scale (Fig. 5). Attempts to map using S-190A and ERTS-1 images (Fig. 6) are much less satisfactory because of coarse-grained emulsion of the former and the telecon fuzziness of the latter.

Bingham Porphyry Copper Mine, Utah.- Using an enhanced enlargement of a S-190B color image at a scale of 1/19,200 of the Bingham Porphyry Copper deposit (Fig. 7) has resulted in poor mapping of part of the geological contact of the Bingham stock and intruded sediments exposed on the pit levels. Comparison of a geological map of the area with the space imagery map is fair for the intrusion boundaries within the pit but of little value for the sediments. Hydrothermal alteration is only slightly evident on space imagery at Bingham but in the Tintic Mining district, Utah, and the volcanic piles of the Keg and Thomas ranges, Utah, hydrothermal alteration is readily mapped on color enlargements of S-190B (SL-3, T3-3N Tr-2).

Calderas, Timber Mountain area Nevada, Escalante Desert, Utah, and Keg and Drum Mountains, Utah.

Several sites of calderas have been recognized and new ones located on space imagery. Attempts to locate the boundaries of three previously suggested calderas in the Topaz, Desert, Drum, and Keg mountain area, Utah, have been made with limited success. The suggested calderas are shown on Fig. 8 with a geologic map of part of the area Fig. 9. New calderas have been recognized and their boundaries have been readily located by ERTS space imagery in the Escalante area, Utah, (Fig. 10) (ERTS-E1447-17412-7) and in the environs of Timber Mountain, Nevada (Fig. 11) (Byers et.al., 1968; Byers, et.al., 1969). Other investigators have also recognized the additional calderas near Timber Mountain and the comparisons of independent mapping of such is remarkably similar (Verbal Comm. by N. Short).

GEOMORPHOLOGY

As the search for hidden mineral deposits in the Basin-Range province extends into post-ore blankets of Quaternary alluvium or volcanics, there developed a need to select those pediment or valley sites where only a thin veneer of alluvial material existed. Such sites required recognition and study of pediments, alluvial fans, bajadas, and valleys with shallow alluvial fill. Some specific examples and applications are:

Alluvial fans.- Image SL-2, 10-007, Tr 34, shows post Lake Bonneville (< 12,000 years BP) alluvial fans where only the fan heads are evident above the Bonneville level. Significantly, the new fans in this area have resulted from recent uplift of this range rejuvenating the source area. The uplift is either tectonic or isostatic rebound occurring after the disappearance of Lake Bonneville.

Bajadas.- Well developed bajadas of this area are interpreted as indicating a state of dynamic equilibrium. In the Snake Range of eastern Nevada, good correlations can be observed between the steepness of fans and the ruggedness of source drainage basins (SL-2, 04-012 to 015, Tr 34).

Death Valley, California.- The patterns of alluvial deposition are easily discernible in the Southern California-Nevada border on space images (SL-2, 04-186 to 192, Tr 6) where throughout the area, numerous observations have been made. This area sharply contrasts with the preceeding one in respect to maturity and activity. In the north end of Death Valley, well developed fans are observable. Individual fans are more distinct on the southwest side than on the northeast side. The north end of the valley is being aggraded by alluvium entering from the northwest.

In the south end of Death Valley, areas of present and recent deposition can be easily distinguished from areas of desert pavement on the southwest fans. There is an absence of desert pavement at the toes of all these fans. The upper limit of this narrow

grey band parallels the fan-playa junction. This feature, along with the differences in size and morphology, are quite probably the result of tectonic activity. The general area is known to be tectonically active and Death Valley is tilting to the East. This tilting may explain the above observations. These interpretations have been done in our laboratory by Robert Rogers.

SEASONAL VARIATIONS OF IMAGERY

Although EREP imagery was acquired during different seasons of the years, ERTS imagery is considerably better in exhibition of seasonal ground variations not only because of snow cover, changes in the sun angle, and more closely spaced time intervals between overflight passes.

The differing views of an area provided by ERTS in the different seasons emphasize different geologic features and patterns. To illustrate seasonal changes in ERTS images and their effect on geologic analysis, the La Sal Mts. area in SE Utah is shown in three differing sets of spectral bands 5 and 7, together with a geologic map and an EREP high resolution photograph of the area (Fig. 12 and 13). In Fig. 12, MSS Band 5 is shown on the left side of the figure with MSS Band 7 on the right. Fig. 12 includes ERTS images and an EREP pass and a geological map with the ERTS imagery acquired on 9/28/72/, and Fig. 13 includes images acquired on 10/29/73/ in the lower portion of the figures and 1/14/73/ in the upper portion of the figures. The contrasts are not strikingly different. This area is of interest for important known and potential uranium and copper ore deposits. The relationships between the La Sal intrusives and the copper and uranium mineralization, particularly on the Lisbon Anticline are most striking.

It is apparent that most of the large geologic units are well defined on the ERTS prints of this small scale. Snow cover and low sun angles emphasize some stratigraphic details and fracture zones and patterns which are obscure on the geologic map and even in the darker portions of the S-190B (Fig. 12) high resolution color photograph.

Two strikingly different ERTS images are shown by Figs. 14 and 15. Both cover essentially the same area but on the two different dates of 12/14/72/ (Fig. 14) (E-1378-17591-7) and 8/5/73/ (Fig. 15) (E-1144-18001-7). This area includes I-80 in the upper portion of the figure with Battle Mountain, Nevada, located slightly left of the upper center of the images. The major mineralized areas are in the Antler Peak range consisting of Copper Canyon and Copper Basin where two open pit operations are active. Both show some evidence on the images of hydrothermal alteration bleaching. Goat Window located to the left of the few cumulus clouds near the center of the summer scene (Fig. 15), is accentuated by the juniper trees that are more prevalent in the limestone window than in the surrounding upper plate allochthonous formations. Tertiary volcanic fields are readily recognized by their characteristic patterns in the upper and left portions of the images.

The winter scene (Fig. 14) exhibits relief exceptionally well along with fracture and fault locations, but offers little for recognition of lithologic changes. The elongate, dark trace in the upper portion of the image is close to I-80 and the major valley in that part of the image, but it does not follow the valley trace well at all and even continues along the east side of the Antler Peak range rather than the major Humboldt river path. Its exact significance is not yet known. The images also include Cortez and the Cedars mining districts.

HYDROLOGY - UTAH LAKE

Soon after ERTS-1 was launched, an enormous algal bloom, swirl pattern was noted in Utah Lake. This is a classic image as shown on Fig. 16. Wind patterns had created the patterns. The prior 18 day overpass on 8/25/72/ (Fig. 17) detected a slight beginning of this algal development that might have been ignored had it not been for the prominence of

the later full development. Interestingly enough, on Aug. 30, no evidence remained and no blooms have been detected since.

There are suggestions of the cause of this algal bloom. Similar but rare occurrences are known in Utah Lake. It is interesting to note that the bloom appears to originate on the west shore of the lake very close to an industrial plant where slurry explosives are developed and tested. There may be a possibility that diesel fuel, nitrates, or other energy sources spilled near the shore could have played a nutrient role in the development of this major algal bloom.

S192 IMAGERY

Cursory analysis of the 13 bands of the S-192 black and white imagery of Utah Lake and the Tintic mining district illustrates the utility of the numerous bands. All channels are located as follows:

	<u>Fig. 19</u>	<u>Fig. 20</u>	<u>Fig. 21</u>
NW Quadrant	2	6	10
NE Quadrant	3	7	11
SW Quadrant	4	8	12
SE Quadrant	5	9	13

Fig. 18 includes, according to the above order of quadrants, the following features:

- Geologic map of the area of a scale of 1:550,000
- Black and white print of Skylab S-190B
- Color print of Skylab S-190B
- Color enlargement of Skylab S-190B

The major feature of Utah Lake, a fresh water lake that drains into the Great Salt Lake located about 40 miles north, are quite variable on the S-192 precision imagery. The lake is most prominent in black reflectivity on channels 4, 5, 6, 7, 8, 10, 11, and 12. None show the details, however of EREP photos on Figure 18. Channel 13, the thermal IR band, indicates a signal to noise ratio of less than one. Geological structural features are well identified, especially in the upper portions of the images on channels 4, 6, 8 and 9. The city of Provo, east of the Lake, is displayed in varying degrees in all 12 channels. The major highway, I-15, is identified more readily on channels 6, 10 and 11. Lake Bonneville strand lines or shore lines are prominently on the mountain slopes in the north portion of the images on channels 5, 7, 8, 10, 11, and 12.

The large Tintic mining district is located in the southwest corner of all images. The EREP color images provide the most detail including the dark and white mottled area located most readily in the lower central portion of the SE enlarged color photo of Fig. 18. This area is the well-known East Tintic district where hydrothermal alteration studies (Lovering, 1949; Lovering, et.al., 1960) have been accomplished, and which led to the discovery of the Burgin Mine. The mottled effect is the result of darker relatively unaltered volcanics in contrast to the well-altered and bleached volcanics. Greater enlargements of this area, in color, would allow better delineation of the altered areas.

In contrast, EREP channels 2, 3, 4, 6, 8, 10 and 11 allow identification of the district but do not provide the detail as viewed on EREP, S-190B, color photos.

S-192 - THERMAL IR STUDIES

Band 13, S-192, is shown in the SE quadrant of Fig. 21. It is obvious that this thermal IR imagery is of low quality and of little use. Being aware of this difficulty, another thermal IR detector (w/X-5) was added to the SL-4 phase of Skylab. Fig. 22 shows the path of this predawn thermal IR track which intersects the California coast north of Los Angeles, covers the southern San Joachin valley, the Sierra Nevada, and crosses Nevada into Utah.

Fig. 23 (ERTS E-1015 17422-7) shows the position of two thermal IR images acquired with the w/X-5 detector carried on SL-4. Clouds cover portions of both thermal IR images and only one image is included in this report.

Detailed analysis of this IR data has not been completed but specific observations have been made. In the Fish Spring range, Utah, however, hot springs are abundant near the northeast edge of the range. The upper left hand corner of Fig. 24 shows the northward discharge or runoff from these springs as white paths flowing over light gray salt flats. The temperature of the springs average around 83°C and the runoff cools slowly over distances of several miles.

MINERAL EXPLORATION

In the Robinson mining district, Whitepine County, Nevada, which includes the Ruth porphyry copper mines, three large positive aeromagnetic anomalies exist over the Ward Mountain area, the Ruth porphyry copper operations, and over a Tertiary volcanic area northwest of Ruth (Figs. 25 & 26). Prior studies of this area have suggested that the volcanics may or may not be the cause of the anomalies. Both ERTS-1 and Skylab S-190A imagery however, indicate possible outcrops in the volcanic area of the Paleozoic sediments. Field studies or ground truth have verified the existence of these inliers. Subsequent to our field study we were made aware of a USGS open file map (Hose and Blake, 1970, USGS open file) of White Pine County, a portion of which is shown as Fig. 27. This figure shows the inliers of Paleozoic carbonate formations overlain by the dacite volcanics. A few areas of Pliocene fresh water carbonate formations overlies the volcanics. Minor modifications have been made in the map and a major fault has been added based on the lack of exposures of rock older than the volcanics in the eastern portion of the area. On this same figure, areas A, B, and C are covered with standard contiguous lode mining claims based on the highly speculative potential of this area.

A magnetic map and gravimetric map (Carlson and Mabey, 1963) of the area is included as Figs. 26 and 28 respectively. Fig. 29 is an aeromagnetic map acquired at an elevation of 600 feet above the ground that shows the magnetic variations in detail and the areas covered by standard contiguous lode claims held by three different concerns.

Carlson and Mabey (1963) realized the suggested potential of the volcanic area of post-mineralization age of the Ruth area and are quoted as follows:

Egan Range. A large magnetic high is centered over the southern edge of the Robinson mining district at Ruth where disseminated copper deposits occur in an east-trending zone of metamorphosed sedimentary rocks and altered monzonite porphyry. The near-surface igneous rocks associated with the copper deposits could produce part of the magnetic anomaly, but the major part is produced by a large, partly concealed, intrusive body.

In the Egan Range northeast of Jakes Valley, Tertiary volcanic rocks are exposed in an area of moderate relief. The gravity values over this area are not markedly different from those on Paleozoic rock in adjoining areas and indicate either that the volcanic rocks are thin or have about the same density as the Paleozoic rocks. The volcanic rocks are covered on the magnetic map by an area of alternate high and lows. The cause of these local magnetic anomalies over the volcanic rocks is not known but the anomalies may be related to intrusive rocks near the surface or the eruptive centers.

The gravity values over the dacite volcanics are similar to those over the Ruth area where a large intrusive underlies the area. Certainly, of course, none of these data is conclusive in indicating a buried intrusive, mineralized, or not, in the northern volcanic area.

Further studies are needed to prove or disprove its existent. It is interesting, however, that the structural trend of the Ruth ore bodies which is essentially east-west, does suggest a change to a more northerly trend that is overlapped by the volcanics as shown by an ERTS image (Fig. 25) and by a S-190B black and white image (Fig. 30). One further study consists of a mercury soil-gas analysis that has been done over part of the area.

Mercury soil-gas analysis.- Mercury is associated with mineralized zones as a trace element, but constantly escapes, ultimately to the surface because of its high vapor pressure. It can be collected readily as an amalgam and can be quantitatively measured by atomic absorption techniques with a precision of ± 2 ppb.

The mercury soil-gas collectors designed under the NASA contracts have been used for almost two years in numerous environs. Measurable amounts of Hg have always been collected, the only exception noted to date is in heavily frozen ground, which appears to form an unpenetrable barrier to the passage of soil-gas. Incidentally, soil samples have been collected at the same sites both before and after Hg soil-gas collecting. There is little if any correlation, presumably because Hg in the soil or rock is probably cinnabar of which the vapor pressure of Hg is nil in contrast to elemental Hg existing in the soil-gas. More detailed research needs to be done on this subject, however.

In practice, the collector cone is buried in the ground to a depth of about six inches and the loose soil that is removed from the hole is tamped down firmly around the outside of the cone. At least two small 1" discs of 180 mesh silver screen are placed in the orifice of the apparatus, and the fan is switched on for a period of ten minutes causing the soil-gas to move out of the soil under the cone and through the screen. Any mercury in the soil-gas is captured by the silver screens forming Ag-Hg amalgam. After collecting, each screen is then placed in a sealed glass vial and refrigerated until it is ready to be assayed in either the mobile trailer or motel room where the portable Lemaire model 500D mercury analyzer is located. The cold environment of storage is a precaution to prevent vaporization of the Hg from the silver amalgam. This procedure is not absolutely necessary, but it does guard against inadvertent exposure to high temperatures while in transit. Blank silver screens are also included after being exposed to air for about 10 seconds or so before being placed in the sealed vials. They usually pick up about zero to 10 ppb of Hg. This determines the contamination level measured in that particular area.

A portion of the results of a mercury soil-gas study of part of the volcanic covered area is shown on the low level aeromagnetic map, Fig. 29. With background measurements of about 10 - 30 ppb, a major anomaly exceeding 120 ppb was located as shown. Because of this anomaly and its location on the flank of the positive magnetic anomaly to the west, this site has been selected for an exploration drill hole test.

Mercury in Geothermal Areas.- The association of mercury with present or past hot spring and geothermal sites is well known. Sulfur Bank, California, for example was a mercury mine until the depth of open-pit mining reached temperatures unbearable to the miners, not to mention the health hazard through inhalation of mercury vapor. Monte Aimata, Italy, has a storage reservoir rock that apparently underwent post-volcanic collapse that fragmented the reservoir rock and the mercury deposits lie below an impermeable thrust sheet that confined and controlled the mercury mineralization. Very few geothermal sites lack mercury mineralization and the resulting escape of mercury vapor to the atmosphere.

This technique has been used in successful exploration for trends of hidden mineral deposits and it has been tested over known ore deposits during the past two years. Recently, however, the technique has been tested over four geothermal areas. Three of the four showed amazing correlation with known geothermal zones within the specific geothermal areas. The fourth area released too much H_2S to obtain valid results and a precipitator of H_2S before it reaches the Ag screen to form Ag_2S is now being developed as an addition to the soil-gas collector. A map of one of the areas is shown as Fig. 31 with the close

correlation of one of the anomalies with a successful geothermal drill hole.

It is apparent, therefore, that this comparatively low-cost exploration tool could be of considerable benefit to those concerns not only exploring for geothermal areas but of important use to better delineate further drilling targets within the area, all of which should be of increased significance to the national concern with geothermal energy resources.

The relationship between mercury mineralization, and hot-spring activity is observed at many geothermal fields throughout the world. In fact, when nuclear or conventional explosive techniques are used to enhance the output of geothermal wells, the danger of post-shot mercury toxicity to human beings will have to be considered, a subject that has received very little study to date.

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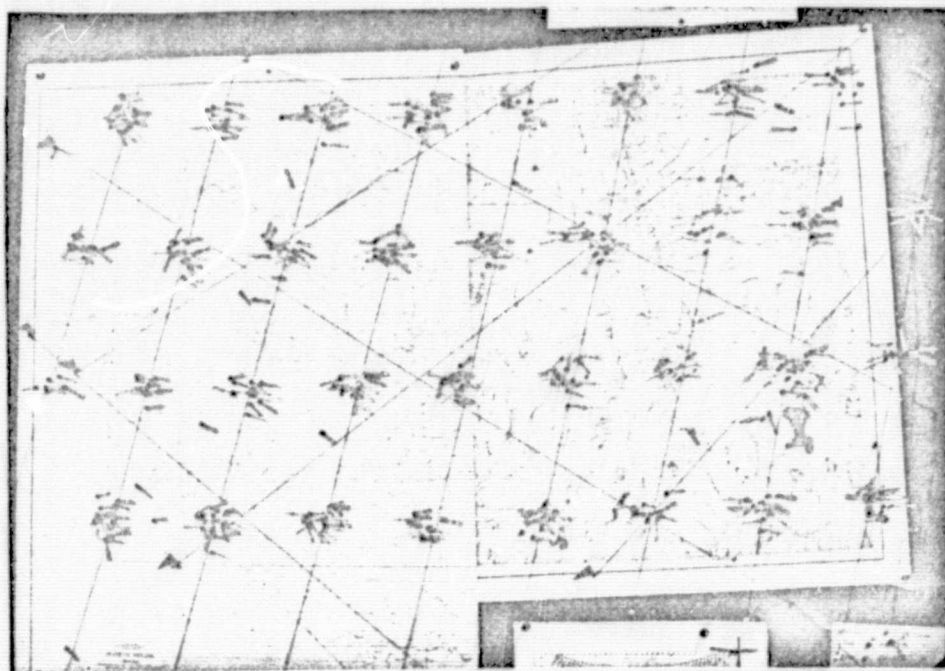


Fig. 1. Location of ERTS-1 images and EREP tracks in the States of Utah and Nevada. Pin colors indicate percentage of cloud cover.

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Fig. 2. Oblique color photograph from Apollo space craft
of Great Salt Lake, Salt Flats, San Rafael Swell,
Utah and Nevada.



Fig. 3. S190B B&W photograph of the Southern portion of the San Rafael Swell, SE Utah. Scale: 1/190,000

Fig. 4. Comparison of Utah State geologic map with cursory map made from S190B photograph. The structural and stratigraphic details on the EREF photograph are evident in detail.

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Fig. 5. Colored geological map of the southern portion of the San Rafael swell for comparison to Figs. 3 and 4. scale 1:380,000.



Fig. 6. ERTS-1 image of the southern portion of the San Rafael swell for comparison to Figs. 3 and 4.

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Fig.6A

Mid section of ERTS color composite centered on San Rafael Desert, SE Utah. This simple inexpensive color combination made from Bands 4, 5, and 7 was balanced to bring out the subtle color-form-texture anomalies which indicate favorable uranium zones in the upper Morrison Fm. near the base of the blue-green Dakota Fm. The San Rafael swell (upper left), Henry Mts. (lower left), and Colorado and Green rivers are shown. Color-form-texture anomalies indicate several zones favorable for detailed field geological, geochemical, geophysical, and shallow drilling work, with possibly more than 10,000,000lbs. recoverable U_3O_8 , with current market value of \$400,000,000.00.

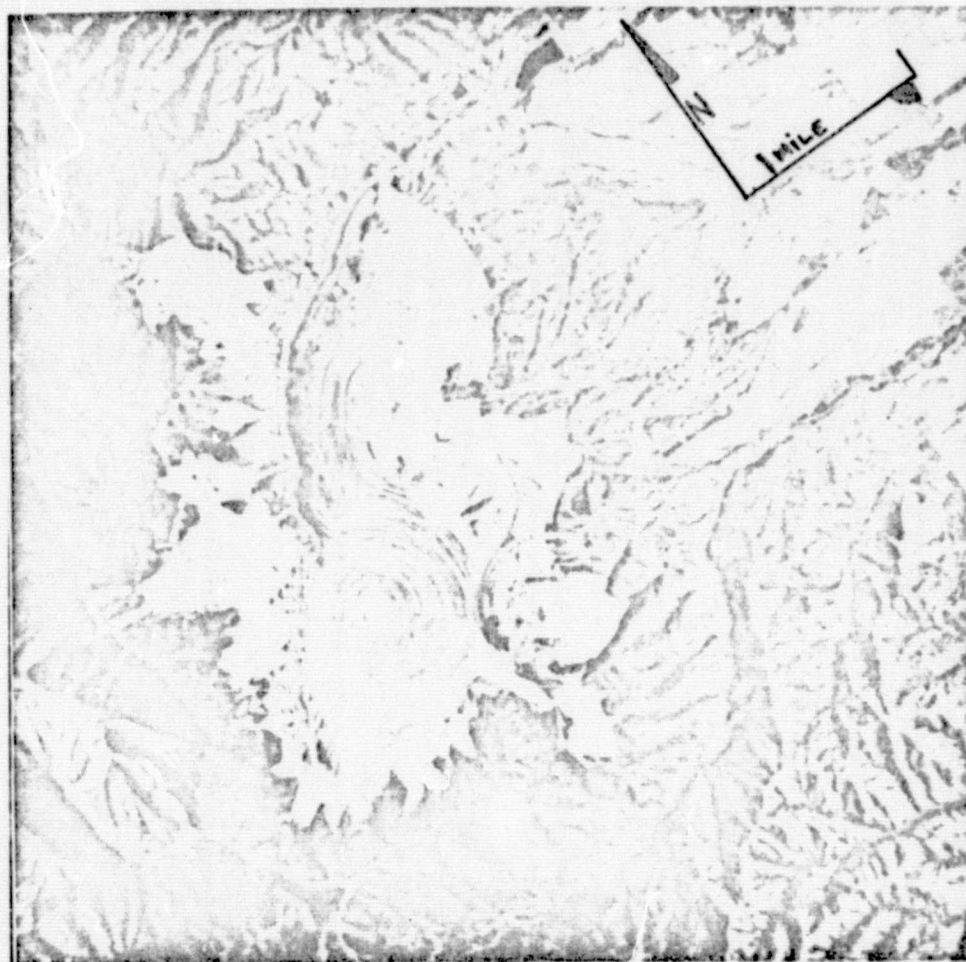


Fig. 7. Color enlargement of the Bingham Porphyry copper pit. S190B image. Although sun shadows cause some darkening of the waste dumps, the darker eastern portion of the pit roughly indicates the position of the granite porphyry Bingham stock.



Fig. 9. Geologic map of two of the suggested calderas that are not well defined on space imagery. Compare with Fig. 8 and part of Skylab photo which covers the calderas.

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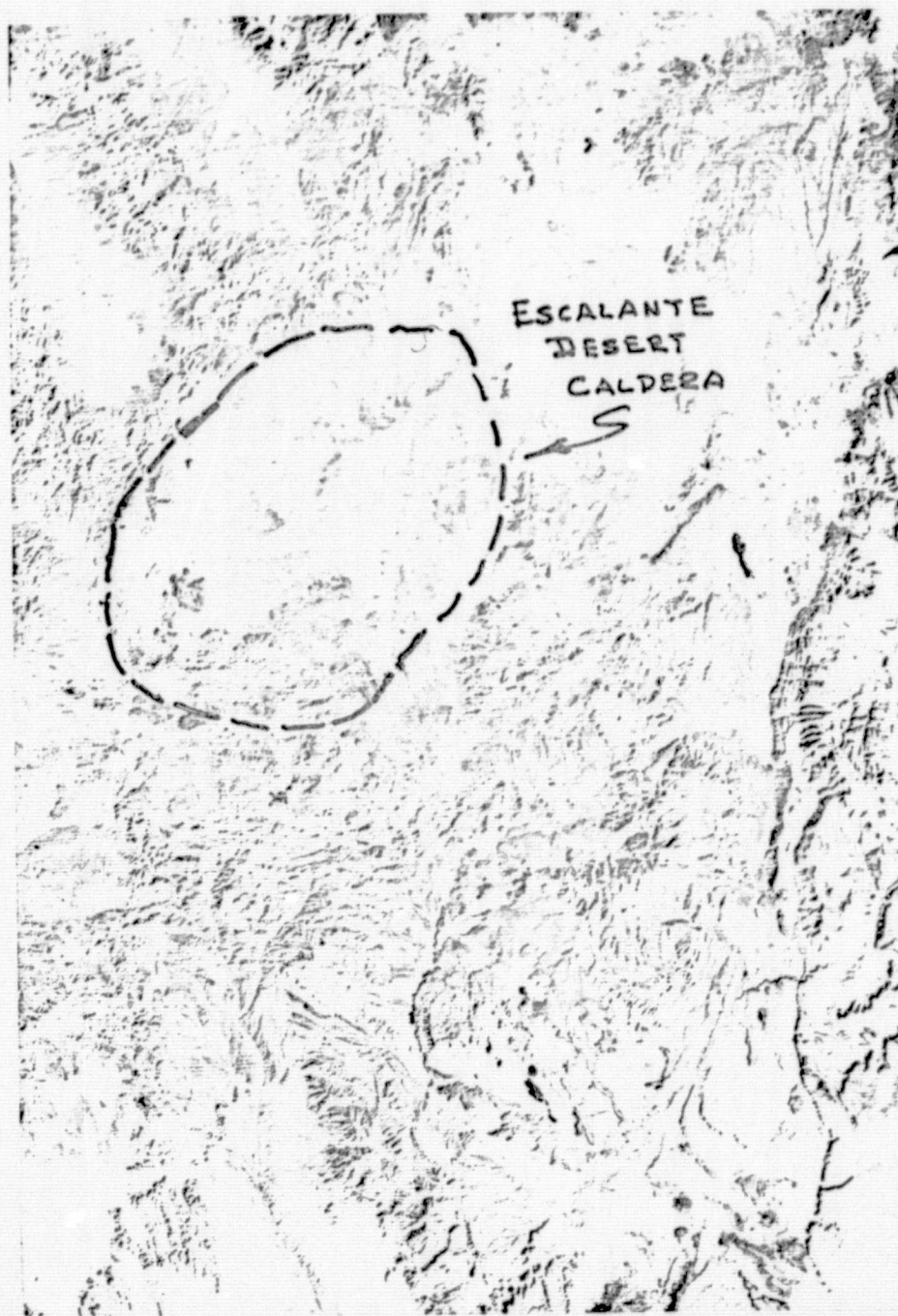
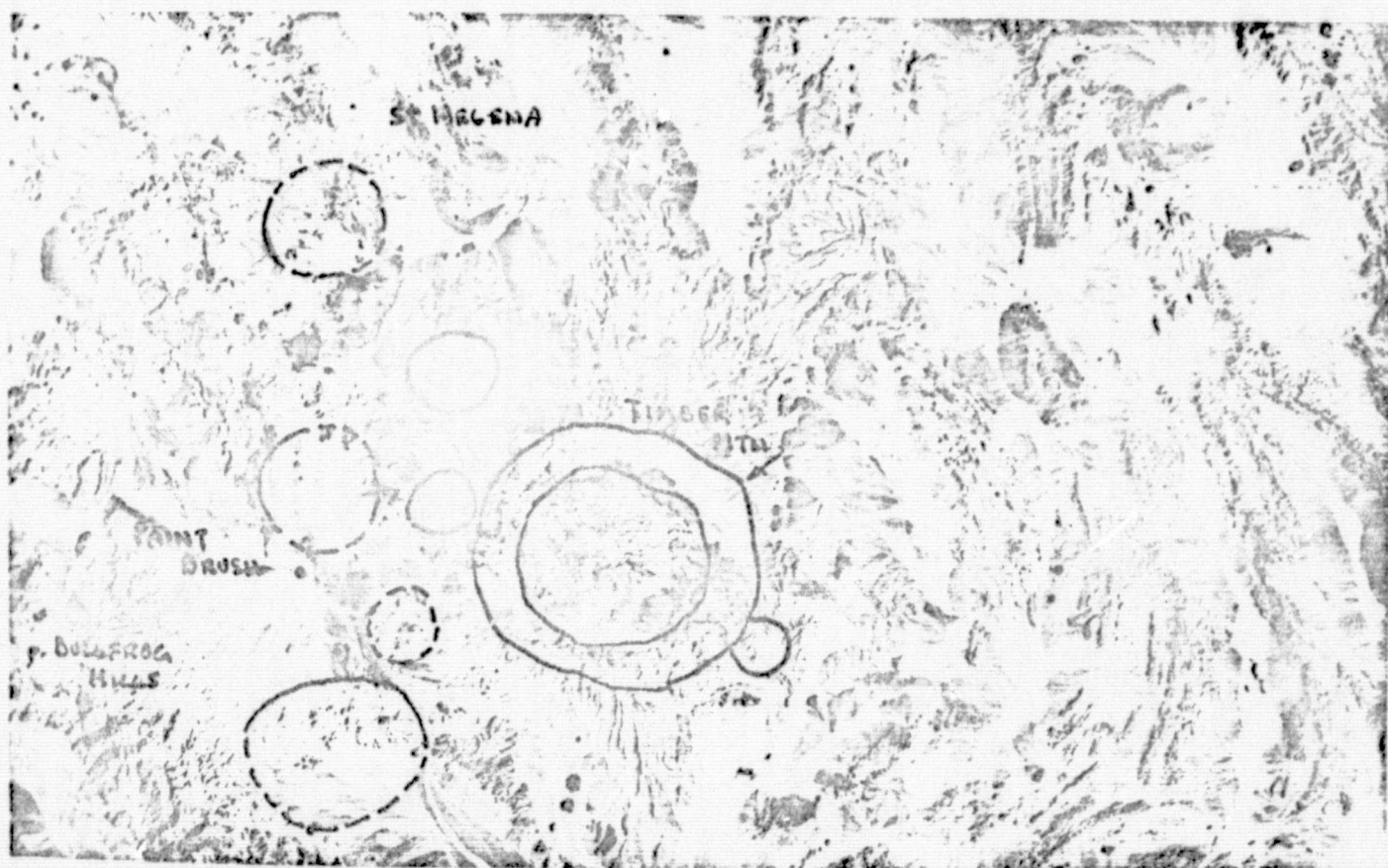


Fig. 10. Well defined Escalante Desert caldera on ERTS-1
image E-1447-17412-7.

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Fig. 11. Calderas of the Timber Mountain area with associated known and newly identified calderas located on ERTS-1 images. Dashed lines were added through interpretation by this study. Solid lines are boundaries recognized by earlier investigators field studies.

Fig. 12. Maps and images of part of the Colorado Plateau,
Utah.

Geologic map

S190B color print

ERTS Band 5
Sept. 28, 1972

ERTS Band 7
Sept. 28, 1972

Fig. 13. Summer-Winter scenes.

ERTS Band 5
Jan. 14, 1972

ERTS Band 7
Jan. 14, 1972

ERTS Band 5
Oct. 29, 1973

ERTS Band 7
Oct. 29, 1972

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Fig. 12.



Fig. 13.

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Fig. 14. Winter snow covered scene, Dec. 14, 1972,
of ERTS E1144-18001-7 image with sun
declination angle of 22 Degrees.

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Fig. 14A. Portion of preliminary Geologic Map of Nevada which corresponds approximately to the ERTS winter-summer photography of the area extending SE from Golconda, Nevada. (Figs. 14 & 15). On this scale--approximately 1:1,000,000, or 1 in.=16mi., the ERTS photos show many apparent geologic anomalies and patterns related to the major copper, gold, and barite deposits in the region which are not present on the geologic map. Special color composites of the ERTS photography provide many times as much geologic pattern anomaly information related to the major ore deposits and comparable targets in the region as the black and white prints.

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Fig. 15. Summer scene, Aug. 5, 1973, of ERTS
E-1378-17591-7 with sun declination
angle of 56 degrees. Compare to Fig.14

Area is northern Lander County, Nevada



Fig. 16. Utah Lake Algal bloom on ERTS image,
Sept. 12, 1972

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Fig. 17. Utah Lake, beginning of algal bloom as
Light streak on ERTS image of Aug. 25, 1972
Compare to full bloom 18 days later Fig.16

Fig. 18 Utah Lake and Tintic Mining District.

Geologic Map

S190B
B&W

S109B Color

S190B
Color enlargement

Fig. 19. S192 images of different channels

Channel 2

Channel 3

Channel 4

Channel 5

Fig. 20. S192 images of different channels.

Channel 6

Channel 7

Channel 8

Channel 9

Fig. 21. S192 images of different channels.

Channel 10

Channel 11

Channel 12

Channel 13
Thermal IR channel



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Fig. 18.

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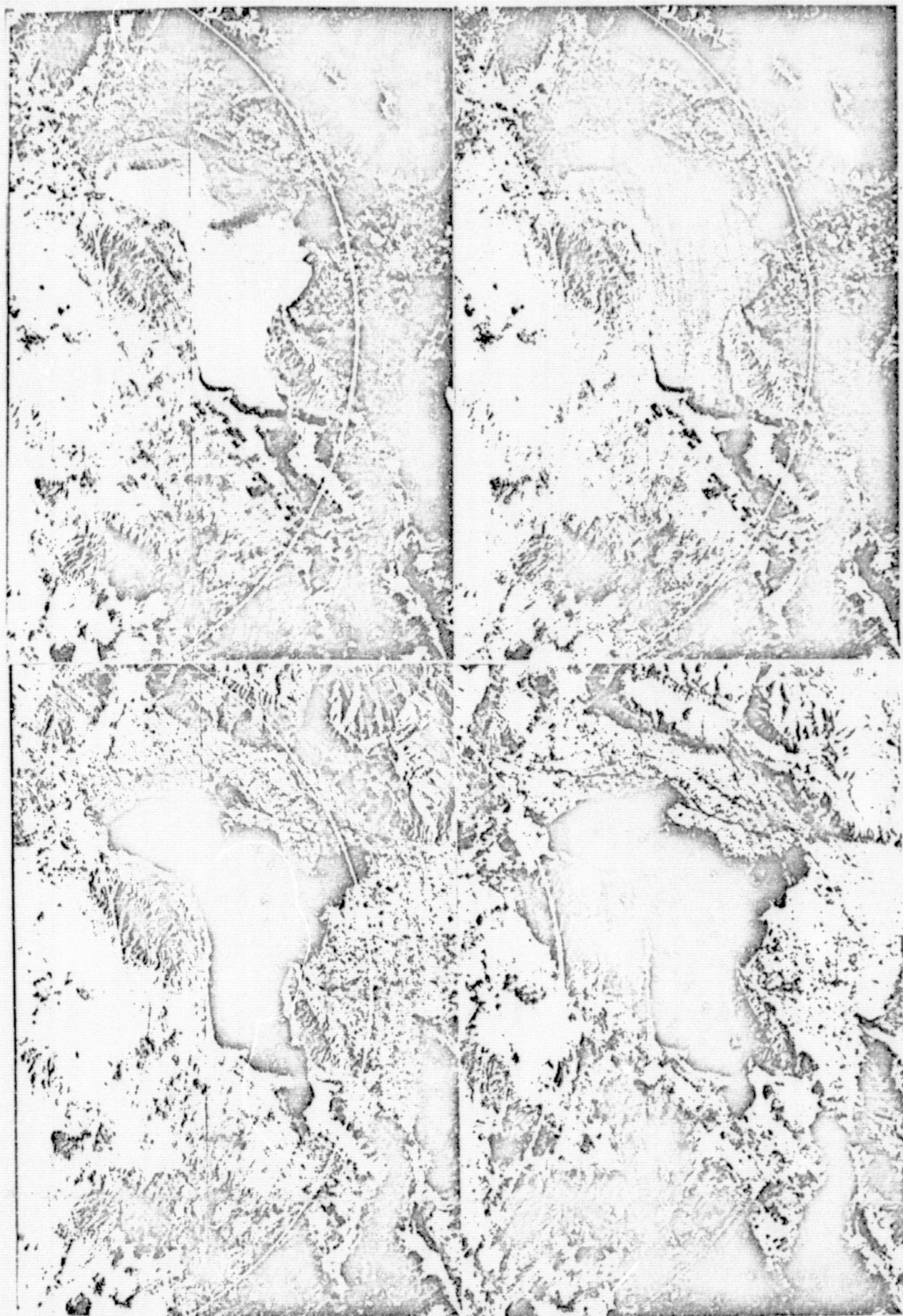
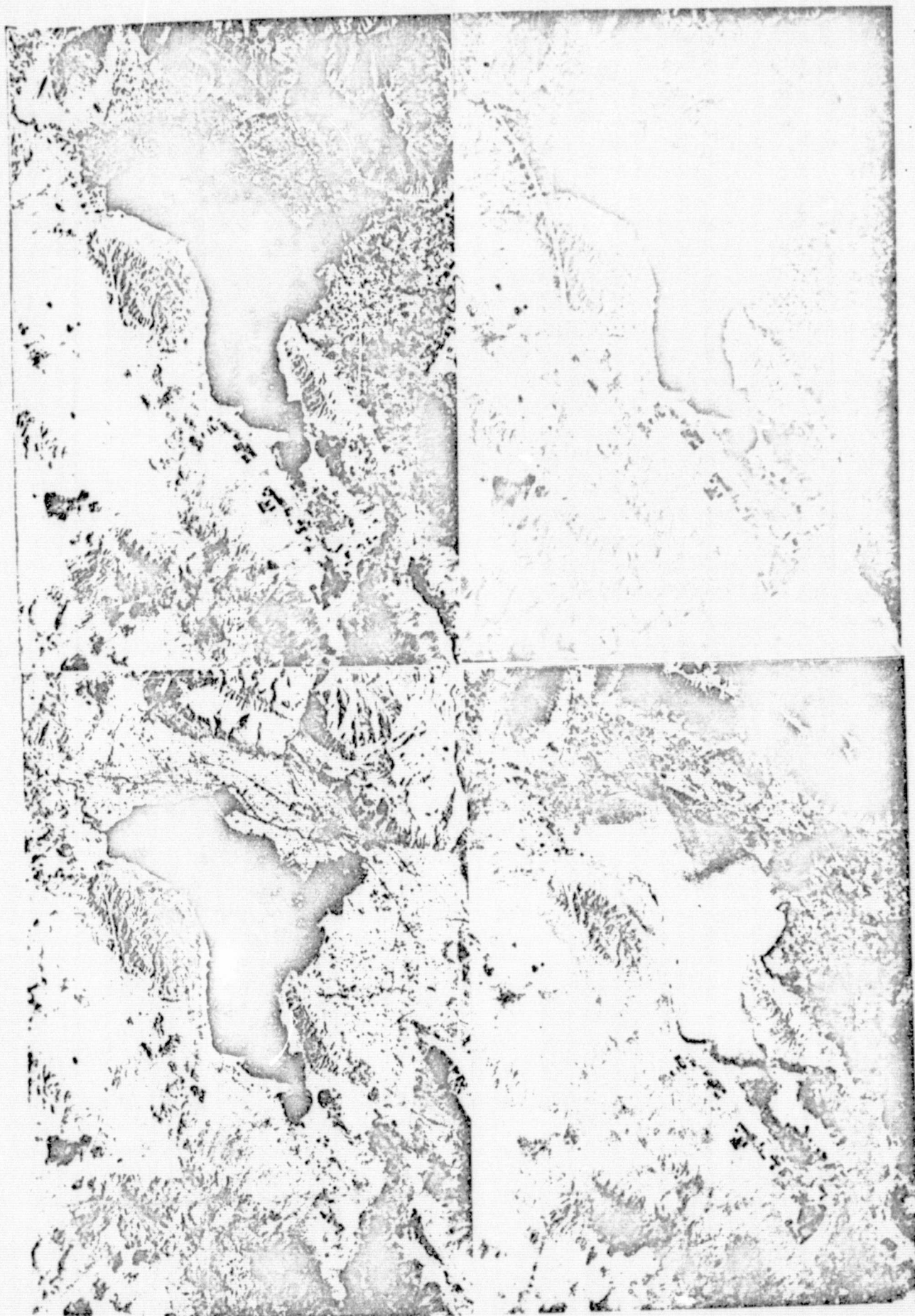


Fig. 19.



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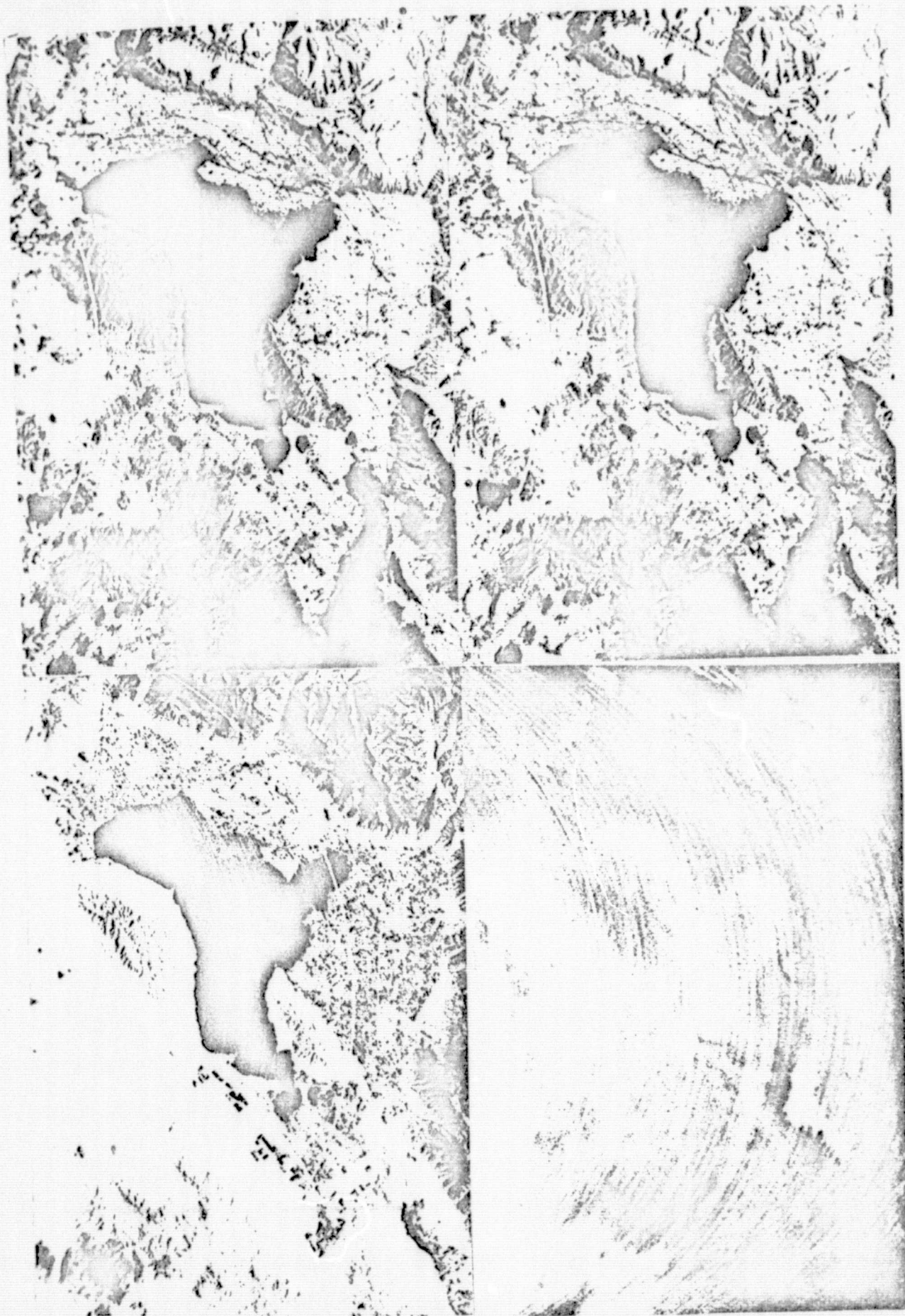
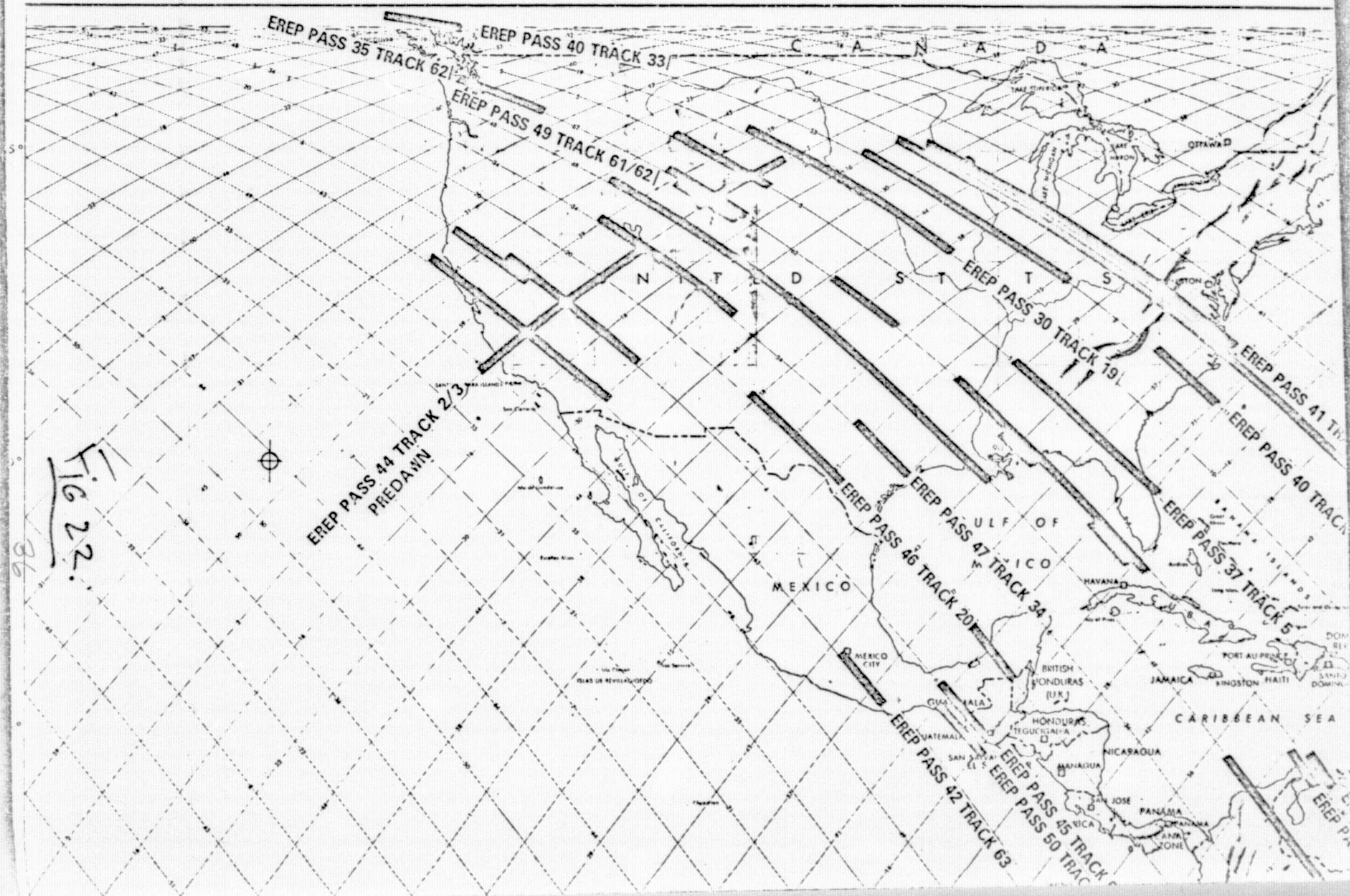


Fig 21

S-192 w/X-5



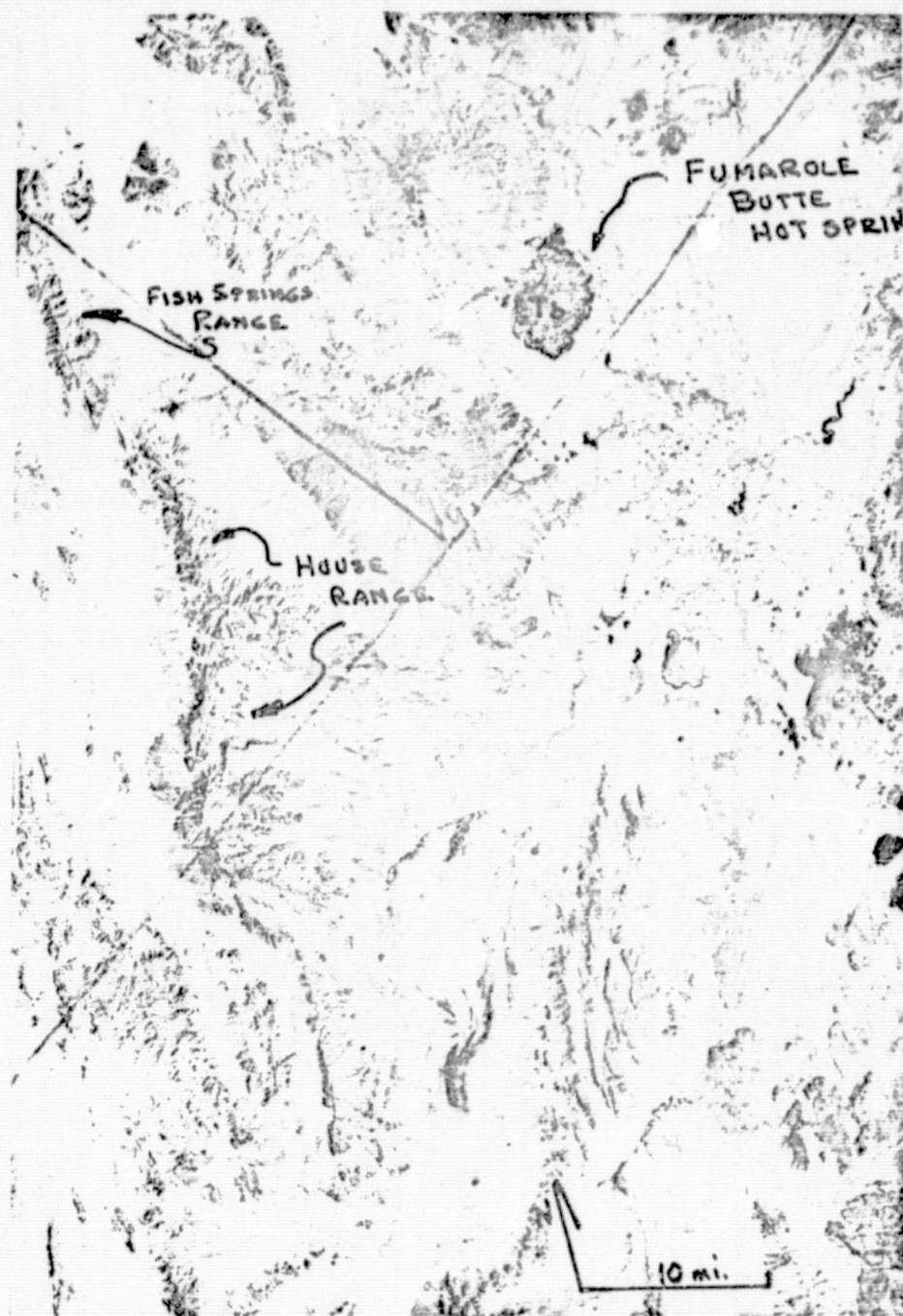


Fig. 23. ERTS image of west central Utah showing position of two precision S192 thermal IR images obtained with the w/X-5 detector. The north edge of the Fish Springs range has several hot springs at temperatures of about 82 degrees C. . Compare to Fig 24.

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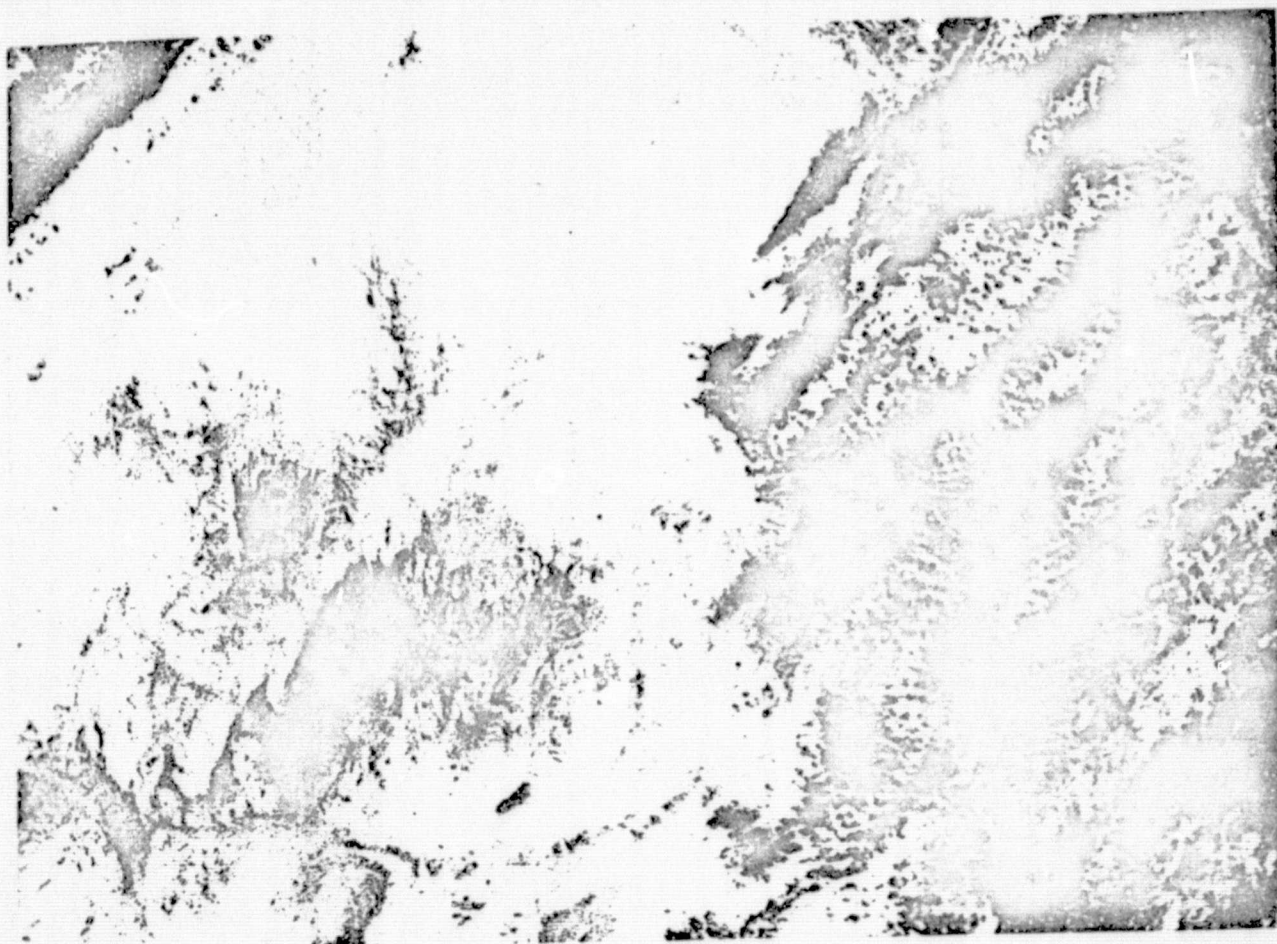


Fig. 24. Thermal IR image of S192, w/X-5 detector precision image. Overflow of hot water from Fish Springs is evident in two parallel discharges in the upper left hand corner of the image.



Fig. 25. ERTS image of Ruth porphyry copper pits, McGill
tailings pond in upper right portion of image,
and dacite volcanic area in upper portion of
image where erosion has exposed outcrops of the
underlying Permian limestone.

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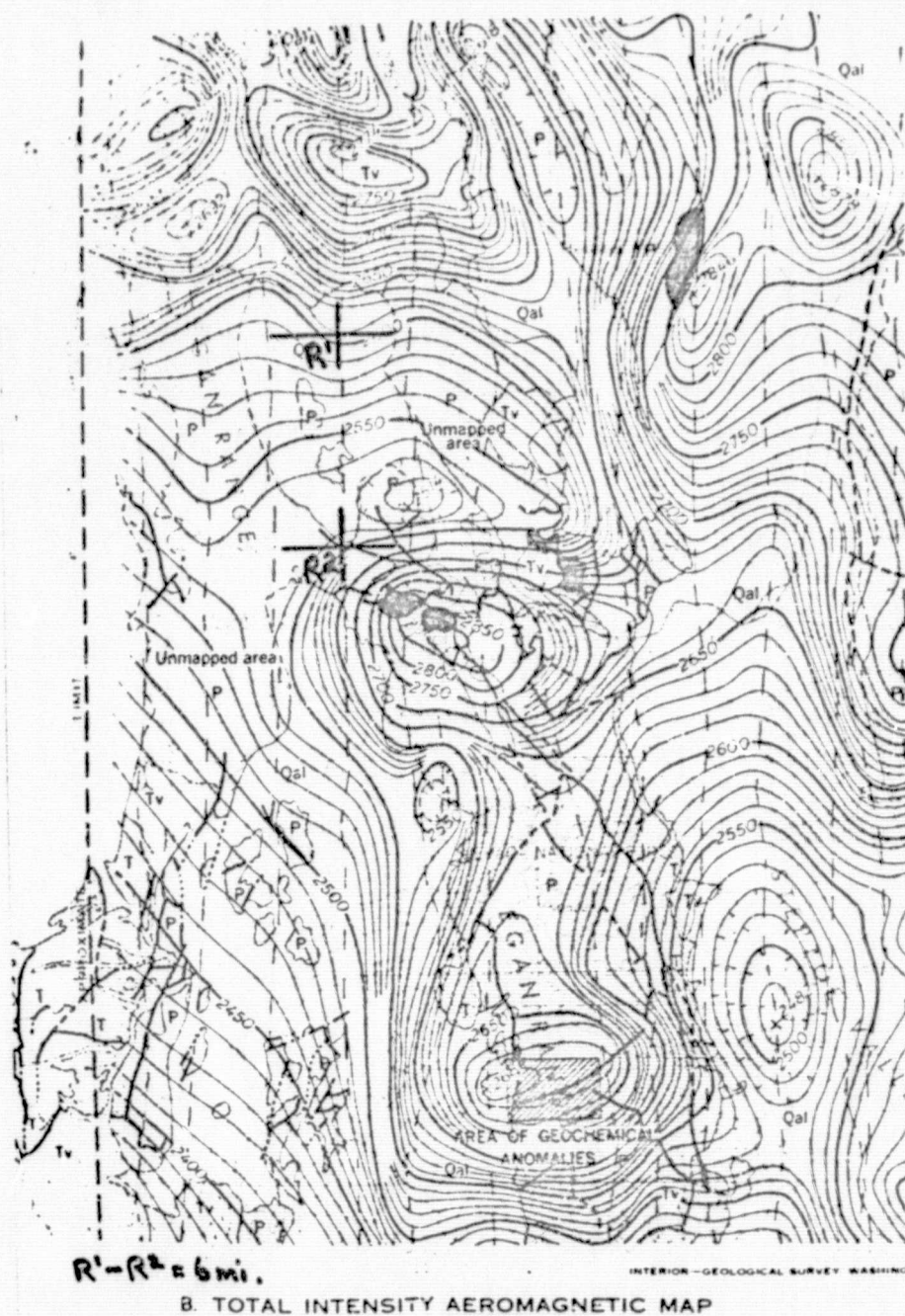


Fig. 26. Total intensity aeromagnetic map of the Ruth area, White Pine County, Nevada showing large magnetic anomalies over the Ruth porphyry copper deposits, the Ward Mountain area of geochemical anomalies in the southern part of the image, and the positive anomalies in the dacite volcanic area to the north.

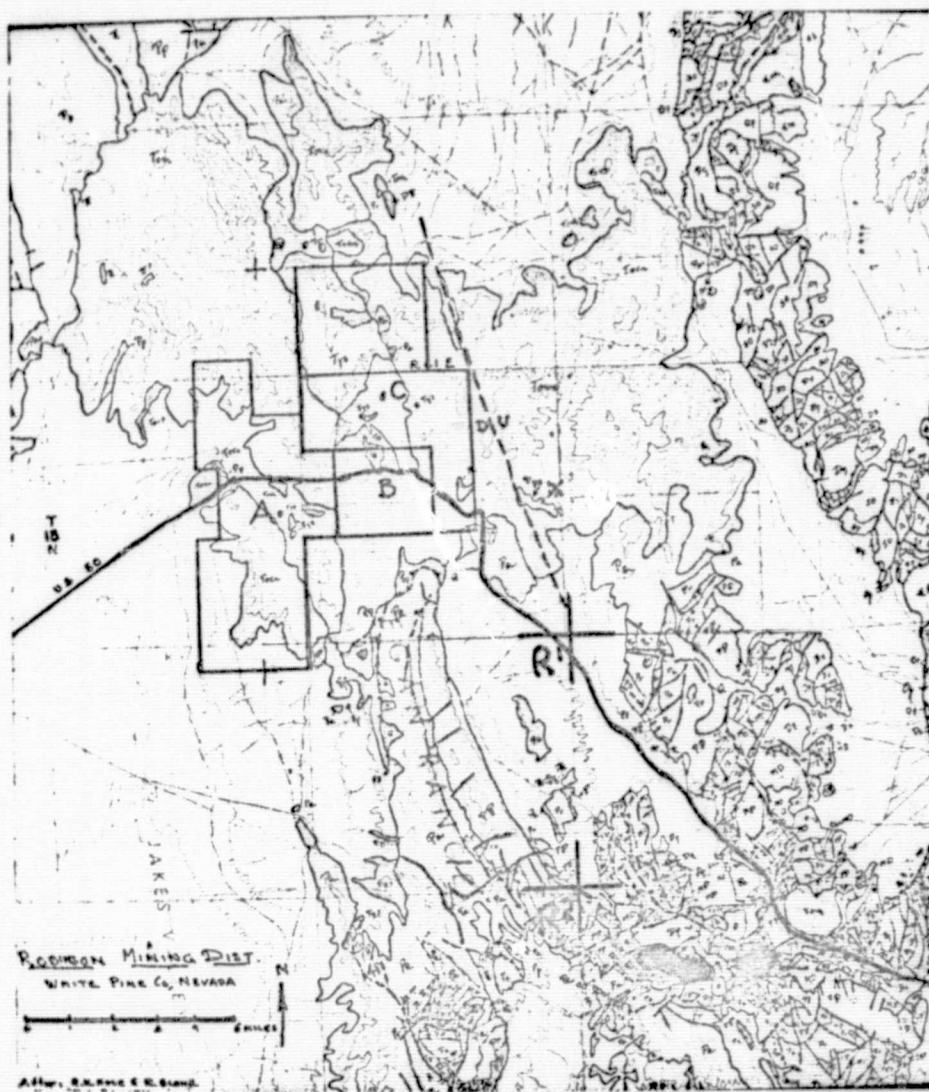
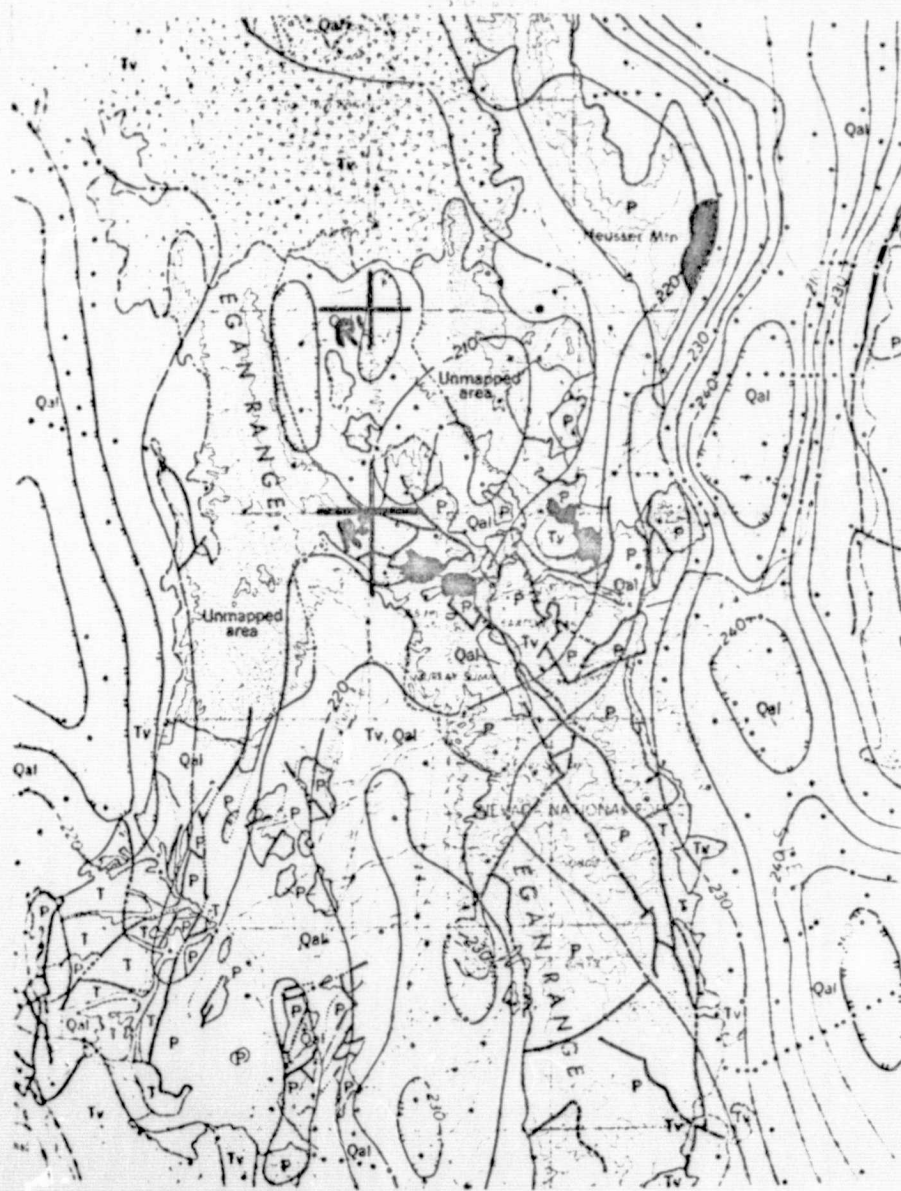


Fig. 27. Geologic map of the Robinson Summit area, Whitepine County, Nevada. The Ruth Porphyry copper deposits are located in the southeast corner of the map. The lettered areas are covered with standard contiguous lode mining claims. (Geology by Hose and Blake, USGS, slightly modified by Jensen)



A. BOUGUER GRAVITY ANOMALY MAP

Fig. 28. Bouguer gravity anomaly map of the Robinson and Ward Mountain mining districts.

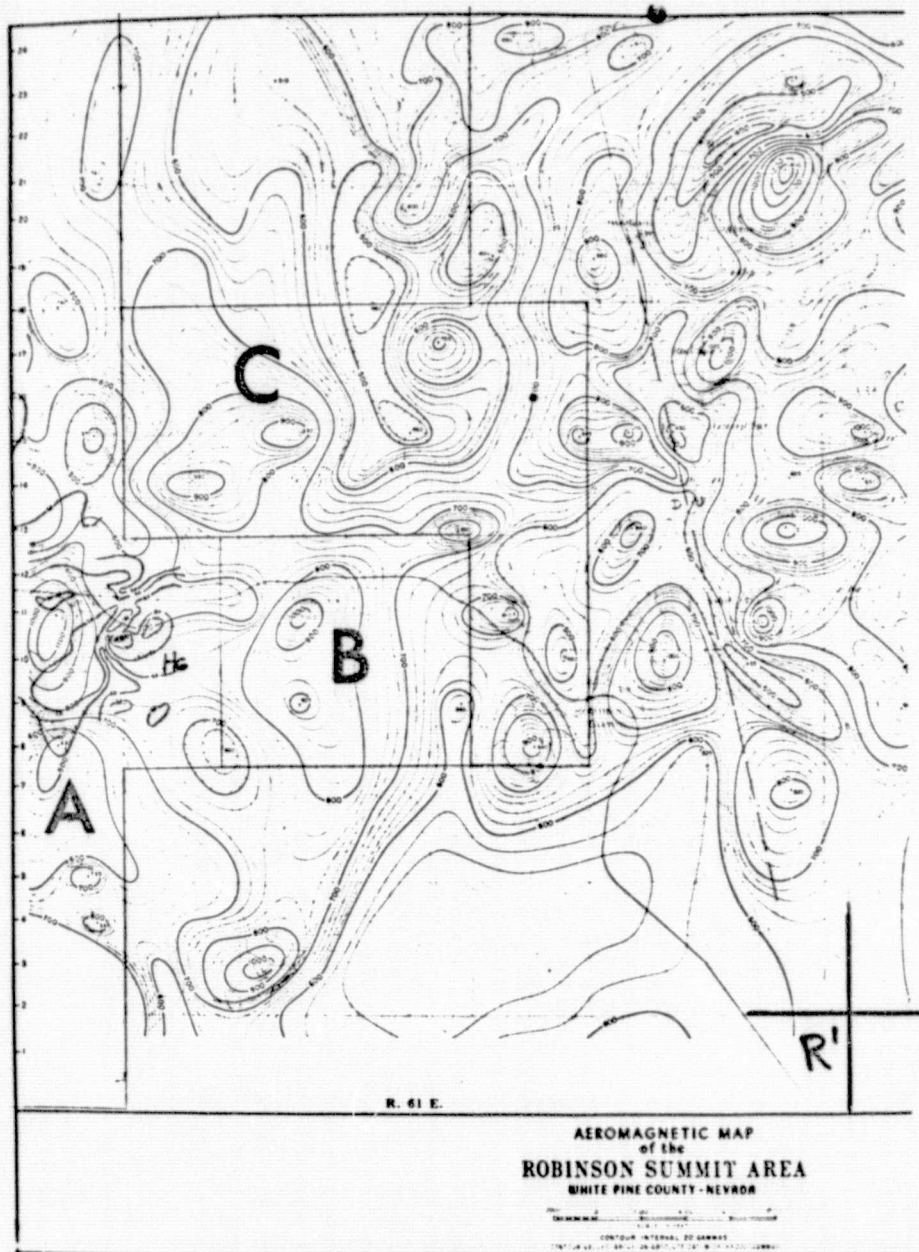


Fig. 29. Total intensity aeromagnetic map of the Robinson Summit area, Whitepine County, Nevada. Lettered areas are covered with standard contiguous lode mining claims and the contours at the left edge of the figure indicate ppb of mercury collected as soil-gas.



Fig. 30. Enlarged U2 photograph of the Ruth Porphyry copper deposits and the structural trend towards the north of Paleozoic limestones to where the dacite volcanics cover the Paleozoic sediments.

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